*The Royal Navy's Vanguard-class nuclear submarine. The Vanguard-class submarines are nuclear powered and armed with Trident nuclear-armed ballistic missiles.*
*(Photo: United Kingdom Ministry of Defense)*

# MODERNIZING FOR THE SECOND NUCLEAR AGE

***The late Martin White, the author of this article, was the head of Strategic Technologies for the Ministry of Defence (MOD) of the United Kingdom (U.K.). He was tasked with ensuring that the U.K.'s defense-related nuclear science and technology capability, primarily centered at the Atomic Weapons Establishment (AWE), is developed and maintained at a level consistent with meeting the MOD's nuclear deterrent policy requirements.***

This article is a personal view, and hopefully it gives a flavor of current U.K. thinking. It reflects my thoughts on the future, what I believe is the continued importance of our nuclear deterrent, and by implication, the importance of the scientific collaborations that underpin it.

## The U.S. and U.K. Partnership

In March 1940 a U.K. memorandum, "*On the Construction of a 'Super-bomb' Based on a Nuclear Chain Reaction in Uranium*," resulted in the establishment that April of the Military Application of Uranium Detonation (MAUD) committee. MAUD was to evaluate the possibilities of a "super-bomb." The following year [1941], MAUD announced it considered "the scheme for a uranium bomb . . . practicable and likely to lead to decisive results in war."

The United Kingdom initially started out alone, under the code name Tube Alloys. However, the scale and cost of the effort led to the recommendation that the project should be pursued under an Anglo-American effort. In August 1943 Prime Minister Churchill and President Roosevelt signed the secret Quebec Agreement. In December the first contingent of British scientists arrived at Los Alamos.

It is from this point on, with a notable gap, that our two nations' nuclear warhead programs have been closely linked. The gap, of course, was a result of the United States' Atomic Energy Act of 1946 [aka McMahon Act], which among other things, prohibited the sharing of any U.S. nuclear weapons information [considered "restricted data"] with another country, even close allies. This meant that the United Kingdom went back to developing its own nuclear program during the time this piece of the McMahon Act was in place. [The act was modified through the signing of the 1958 U.S.–U.K. Mutual Defence Agreement to allow nuclear information sharing.]

*Cloud from the United Kingdom's Operation Hurricane atomic bomb test, October 3, 1952 . (Photo: Open Source)*

## The U.K. Nuclear Program

Since 1959 we have retained close collaboration. It is worthy of note that by 1952 the United Kingdom had exploded its first atomic device: Operation Hurricane, a plutonium fission bomb. Rapid development of more-powerful designs followed, including the test in 1957 of the first U.K. thermonuclear bomb design. The United Kingdom went on to develop a number of warheads fitted to a variety of air-delivered weapon systems, from Blue Danube [1953] and the WE177 free-fall bomb [1966] to nuclear depth charges.

The inevitable development of standoff weapons and terminal defenses meant that a step-change in the development of strategic systems was required from the 1960s forward. The procurement of the Polaris missile [a U.S.-designed and -built, nuclear-equipped, submarine-launched ballistic missile (SLBM)] represented that step-change for the United Kingdom in the maintenance of our nuclear deterrent and a further development in a much closer relationship with, and dependence on, the United States.

While the subsequent U.K. Chevaline program [meant to improve the Polaris weapon system] represented a return to a greater level of U.K. independence, the purchase of the Trident II D5 strategic weapon system [another U.S.-designed and -built, nuclear-equipped SLBM] marked a further development in our collaboration with the United States.

In 1994 the declared maximum number of warheads taken on a U.K. Trident patrol [U.K.'s Vanguard-class nuclear submarines, armed with U.S. Trident II D-5 SLBMs] was 96. After the 1997 "Strategic Defence Review" [published in 1998], reductions were made, resulting in 48 or fewer warheads per boat, and the total stockpile was reduced from 300 to fewer than 200. With fewer warheads came fewer missiles, and the U.K. purchase order went from 65 to 58.

So by the end of the 1990s, the United Kingdom was reliant on a single nuclear deterrence system—something that had not happened since the 1950s. And so it remains today.

**By the end of the 1990s, the United Kingdom was reliant on a single nuclear deterrence system—it remains so today.**

The United Kingdom operates a minimum credible deterrent. It fields a single Vanguard-class submarine [from a fleet of four] with up to 40 warheads, on patrol at all times, in a posture we call Continuous at Sea Deterrence (CASD). CASD also forms part of our commitment to NATO.

It is therefore of paramount importance that this single-system capability, reliability, and effectiveness is maintained and is not eroded by age, obsolescence, or emerging threats.

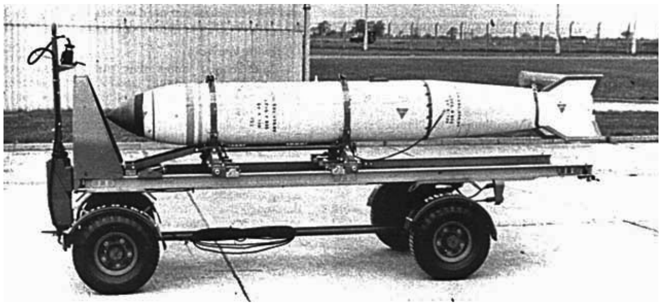
## The U.K. Stockpile Stewardship Program

Since the cessation of nuclear testing and ratification of the Comprehensive Test Ban Treaty [CTBT] in 1998, U.K. confidence in the nuclear weapon stockpile has been maintained through the development and exploitation of a program of science-based stockpile stewardship activities. And that scientific understanding is firmly rooted in our collaborative efforts that can be traced back to the 1943 Quebec Agreement.

Demonstration of our deterrent capability now rests in part on our commitment to sustaining large-scale investments in the cutting-edge facilities and science that must now underpin, what I would call *assure*, the U.K. deterrent warhead.

Our confidence in our warhead capability and performance is underwritten through the credibility of our scientists and engineers and our Nuclear Weapon Stockpile Management Program, conducted mainly at the AWE. What is important is that much of this work is peer reviewed by American subject-matter experts, including our colleagues here at Los Alamos.

*The 24-foot-long Blue Danube was the first nuclear weapon stockpiled by the United Kingdom, beginning in November 1953. Based on the Hurricane, it was of limited production and basically built in a laboratory setting. (Photo: Open Source)*



*The WE177 was the last U.K. air-delivered, free-fall nuclear weapon. It was deployed during the late 1970s and retired in March 1998, ending the U.K. aircraft-carried nuclear weapon capability.* (Photo: Open Source)

As the stockpile ages, and materials and processes change, we must examine our weapons for signs of degradation, predict the effects of these changes, and be ready to refurbish or remanufacture our stockpile of weapons. We are ever more reliant on accelerated-aging trials data and predictive aging models to give us the extended warning window we need to respond with our manufacturing capacity. These are concerns both countries share.

Once built, refurbished, or remanufactured—or perhaps, depending on political decisions, eventually redesigned—U.K. warheads must be certified *in the absence of underground tests*. This certification process requires unique capabilities:

- Supercomputing, which allows numerical models to be developed and used to predict material behavior and performance in the environment of an operating nuclear weapon.
- Hydrodynamics, which generates the necessary data to test and develop these models, particularly for the nuclear primary.
- High-energy-density physics experiments, which yield data relevant to thermonuclear burn, radiation transport, and operation of the nuclear secondary.

The United Kingdom has had decades of experience in pursuing this predictive modeling approach. We conducted much fewer nuclear tests than other nuclear weapon states—some 40 compared with over 1,000 for the United States—partly because we had an intensive aboveground experimental program and a strong model-based strategy for certification of nuclear yield. The same model-based approach is being exploited to do the following:

- Predict warhead behavior throughout the stockpile-to-target sequence and provide assurance of warhead survival and successful operation.


*A Polaris SLBM on display in the Imperial War Museum. The U.S.-designed Polaris missile was later improved through the U.K.'s Chevaline program. The improvements included a sophisticated decoy package to counter the Soviet Union's anti–ballistic missile defenses.* (Photo: Open Source)

*A Trident II missile being test fired from a Vanguard-class nuclear-powered submarine. The first batch of British Trident warheads was completed in September 1992. The warheads were designed by the AWE and are probably similar to the U.S. W76 warheads now on U.S. Trident missiles. Production of the British warhead ceased in 1999.* (Photo: Open Source)

- Plan scenarios and consequences of execution.
- Predict warhead survivability.
- Manage boat manifests against the life of the out-loaded warheads.

Our assurance of the effectiveness of our nuclear deterrent is a direct result of these studies and of the resilience of our capabilities in terms of people, facilities, equipment, and programs.

## Modernizing the U.K. Nuclear Weapons Program

You may know that we are in a period of *major* investment at AWE in terms of workforce, facilities, and programs. In the past decade, the workforce has grown from a low of 3,000 to the current 4,500. That represents a huge challenge and culture change for AWE: training the new workforce, at the same time as delivering the program and at the same time as the site recapitalization presses forward. The facilities-build program aims to replace much of the 1950s infrastructure at AWE, with 4 major projects and over 30 others underway.

By the end of this decade, we will have new uranium, high-explosives, and assembly facilities. Just as crucial, we will have a state-of-the-art high-power laser, supercomputing, and new hydrodynamic experimental capabilities. This last, the Teutates project, is a groundbreaking Anglo-French facility being constructed in Valduc, France. It will achieve initial operating capability in two years' time and when it is complete will be the most capable hydrodynamics facility in the world.

And this investment in the future is *not* just at AWE. We are developing our next generation of naval nuclear reactor plants. We are, together with the United States, building a common missile compartment for the next generation of ballistic submarines.

Since issue of the 2006 white paper, "*The Future of the U.K. Nuclear Deterrent*," the government has spelled out its continuing commitment to maintaining a ballistic, submarine-based nuclear deterrent capability. This was expressed most recently by our prime minister on the occasion of the completion of the 100th Vanguard patrol [on April 3, 2013], when he set out the arguments for renewing our Trident missile deterrent system.

Although we have been described as one of the most reluctant nuclear nations to own a deterrent, I would argue that the ab initio way in which deterrence policy is generated (as in the 2006 white paper), along with the transparency that attends the ensuing debate, means that the strategies formed as a result are stronger and all the more defensible for it.

## U.K. Nuclear Stockpile Reduction

We can also point to a proactive stance when considering deterrent reductions. The 2006 white paper confirmed a further reduction of the operationally available warheads from a limit of 200 to a limit of 160. This represents a halving of the operational stockpile since 1997. As our then secretary of state Des Browne commented in 2007, this left us with the smallest stockpile of all the recognized nuclear states.

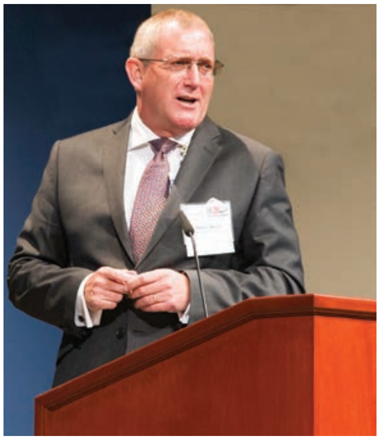
In the 2010 "Strategic Defence and Security Review," the stockpile was reduced by a further fifth, to no more than 120 operationally available warheads out of a stockpile of no more than 180.

So what does all this mean in terms of lessons for the future?

> **When Teutates is completed, it will be the most capable hydrodynamics facility in the world.**

## The Equation of Deterrent Costs

In terms of affordability and sustainability, the reductions have made little or no difference. There have been some



*The late Martin White speaking at the 2nd Los Alamos Primer lecture series, held in celebration of the Laboratory's 70th Anniversary.* (Photo: Los Alamos)

savings on missile procurement, but in terms of warheads, our major cost is opening the gates to a safe and secure AWE site. The only way you can influence the equation of deterrent costs is to do one of the following:

- Reduce the number of deterrent systems. But we have only the one: Trident missiles.
- Move to a cheaper, but still effective and credible, deterrent system. Successive and exhaustive studies over the last few years have consistently shown that the terms "cheaper" and "effective and credible" are mutually exclusive where U.K. nuclear deterrence requirements are concerned. The government has just completed the Trident Alternatives study. The study makes no recommendations because it was a neutral, fact-based analysis and not designed to change government policy—which is to maintain a continuous deterrent and to proceed with the government's program to build a new fleet of ballistic missile submarines.
- Build a system that lasts forever with little or no maintenance. This is not feasible, and anyway, what happens to your nuclear expertise in the meantime? We're still busy recapturing and exercising capabilities lost in the last 20 years since the building of the Trident system.
- Get even greater efficiency through collaboration between nuclear weapon states. We have the 1958 U.S.–U.K. Mutual Defence Agreement and the Polaris Sales Agreement with the United States. And we have a 2010 treaty with France through which we are delivering the Teutates project. But there is *definitely* room for growth in collaborations. However, these take time.

## Future Arms Reductions

We expect negotiated arms reductions to follow a predictable path: a continuous, smooth mathematical function, if you will. There is, so far, no strategic shock envisaged. That implies that the process will be pursued with a focus on our need to maintain a capability to meet policy needs. So the question of conflict between deterrence requirements, deterrence assurance, and deterrence reductions does not occur, at least for the foreseeable future.

We also need to recognize that we cannot simply turn our nuclear capability off and on. History has taught us that reinstating a lost or reduced capability is a very expensive exercise.

Finally, we must guard against strategic imbalance and the impracticality of arms reductions verification: an equation that gains relevance as numbers reduce. In anticipation of the United Kingdom's eventually being included in multilateral arms limitation discussions, the United Kingdom has a healthy program of research into arms verification technologies. These methodologies are exercised in lifelike conditions with the United States and, for added realism, a third party: Norway.

This strategy follows a well-worn path. In the past, we found great advantage in understanding the full implications of the CTBT for our nuclear weapons program by scoping and researching the applicable technologies invoked by the treaty. To do otherwise would be to jeopardize the sustainability of our deterrent program and to risk the adoption of ineffective measures of treaty verification.

> **Continued close work with Los Alamos lies at the heart of the U.K. program's sustainability.**

In all this, our interactions with the United States have been and remain pivotal in shaping the U.K. deterrent program. And our continuing collaborations with Los Alamos National Laboratory touch the very core of our technical capability.

This is best evidenced by our recent collaboration on trials at U1a [a test facility at the Nevada National Security Site], where independent U.K. predictions of performance were compared with the experimental data. This represented a significant peer review, given that more data were gathered in those two trials than were collected during the entire pre-CTBT nuclear test program. The good news is that predictions and data matched quite well. And the United Kingdom continues to field experiments on the Los Alamos Dual-Axis Radiographic Hydrodynamic Test facility and has secondees within the Los Alamos weapons design teams.

In the area of national nuclear security, our teams continue to challenge and peer review each other, with exercises conducted by U.K., French, and U.S. experts. It is clear to me that our collaboration and, within it, our continued close work with Los Alamos lie at the heart of the U.K. program's sustainability.

*~Martin White*